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Regional Case Study

Decision-Making Strategy of Hospital Waste Management Using the TOPSIS Method

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Abstract

Clinical waste is likely to include disease-causing microorganisms, chemical wastes, and other treatments used to treat different conditions, whether solid or liquid. As a result, clinical wastes have a more significant potential for pathogenicity and toxicity than most other types of waste in all of their forms. This study aims to design a strategic decision model for managing medical waste from hospitals. The method used in this research is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). The data was collected using a questionnaire distributed to three people from various fields: hospital waste management experts, academics, and the environmental service. The results show that the preference for the best hospital waste management strategy is SOP improvement with a weight of 0.6576. Furthermore, the alternative of investing in environmentally friendly technology, 3R campaigns, and outreach to employees and visitors received a weight of about 0.4885, 0.2973, and 0.3393, respectively. This study can be a reference for research related to decision-making strategies and the field of hospital waste management.

Keywords: Clinical; hospital; waste; decision; TOPSIS

1. Introduction

Managing garbage from hospitals and other healthcare facilities will be one of the greatest issues in the contemporary world. Incorrect handling of hospital waste can threaten the population's health and the surrounding environment (Chartier, 2014). Ho and Chen (2017) revealed that improper treatment of clinical waste results in the transfer of various deadly infections, including hepatitis B, C, and human immunodeficiency virus (HIV). Consequently, it may be said that the inappropriate handling of medical waste poses a grave risk to human health.

Throughout patient treatment, vaccination, and diagnostics, medical institutions and hospitals produce clinical waste. Health waste is divided into two categories: general waste and infectious waste (Abd El-Salam, 2010; Patwary et al., 2011; Hossain et al., 2011). According to a report published by the World Health Organization (WHO) in 2013, 75 to 90 percent of trash from medical institutions is non-hazardous, while the remainder is categorized as infectious (Chartier et al., 2013). In addition, in developed countries, using high technology and single-use equipment encourages the emergence of hospital waste to be greater than in developing countries (Manga et al., 2011). Waste management in industrialized countries is governed by modern technology, data management systems, and laws that are simple to implement owing to the availability of adequate resources (Iqbal et al., 2017).

Various studies have highlighted the problem of inappropriate hospital waste management practices in developing countries. Nowadays, the medical institutions do not process and dispose of their whole harmful biological waste. Typically clinics employ government and non - governmental policy waste management facilities to dispose of or manage trash (Ho and Chen, 2017). A study conducted by Windfeld and Brooks (2015), states that "There is no proper waste management system in most developing countries." In the third world, the management of medical waste is assigned to local garbage handlers lacking particular training or instructions on how to treat this material effectively (Khan et al., 2019). A research done in India similarly revealed that incorrect health waste disposal procedures, no effective classification, and no safe treatment and disposal had been extensively documented (Diaz et al., 2005). These facilities routinely dispose of their medical waste in communal trash cans, which should always be used as municipal garbage (Patil and Shekdar, 2001). According to a survey from Bangladesh, the majority of healthcare institutions do not properly dispose of medical waste, and just a few medical institutions adhere to the regulations. According to the same investigation, medical waste management personnel were unlawfully reusing sharp tools, salt containers, medical supplies, and other resalable objects (Anisur et al., 2008). Numerous healthcare institutions utilize a variety of removal techniques, including burning, dumping, burial, and recycling. In addition to these Asian nations, additional research undertaken in asset nations such as Brazil, Jordan, Iran, and Ghana have shown comparable outcomes (Manga et al., 2011).

Indonesia has severe controls regarding the disposal of clinical waste. Those who breach the requirements will be penalized and required to make adjustments, and any exposure of information about such infringement might result in a prestige loss for the hospital. Studies related to hospital waste management strategies in Indonesia have not been widely carried out, and this raises the question of how hospitals decide on the right company to do the work is a question on several criteria. Therefore, how the hospital chooses the ideal medical waste management through an objective selection mechanism/model.

The use of decision-making methods in waste management has been widely studied (Coelho et al., 2017). The selection of dump sites, for instance, is classified as a multi-attribute decision-making problem, requiring consideration of multiple factors in determining dump places (Paul, 2012). Various scholars have developed various methods of decision-making in the past. The use of defuzzification (Ariasih et al., 2015), revised fuzzy effectiveness (Singh & Dubey, 2012), fuzzy multi-objective linear programming (Shaw et al., 2012), and the integrated fuzzy approach are examples of fuzzy method methods (Ariasih et al., 2015; Kharat, et al., 2016). The analytical hierarchy process (Boskovic & Jovicic, 2015) and VIKOR are different methods (Opricovic & Tzeng, 2004; Liu et al., 2014). Furthermore, several academics blend decision-making approaches alongside geographic information systems (Chabuk et al., 2016, Torabi-Kaveh et al., 2016). Additionally, a decision support system for facility location associated with multi decision making has been established (Alves et al., 2009). Moreover, study conducted by Rimantho and Tamba (2021) analyzed a decision-making model on waste management in Burangkeng landfill by applying the SWOT and AHP methods.

TOPSIS is a multi-attribute decision-making approach (Asadzadeh et al., 2014). TOPSIS is often linked to AHP for discovering the optimal solution to a problem (nüt & Soner 2008, Ertug rul & Karakasog lu, 2008, Beskese et al., 2015, Zakerian et al., 2015). Improving waste management in hospitals requires careful strategic analysis of waste management problems. Based on the previous description, this study aims to build a model to analyze decision-making strategies in the management of medical waste from hospitals. Hospital waste management requires strategic decision making in order to find long-term solutions. Strategic decisions contain specific criteria that distinguish strategic decisions from other decisions. Thus, the overall goal of strategic decision making is to obtain alternative strategies for hospital waste management so as to gain a long-term competitive advantage and avoid environmental degradation.

2. Methods

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), established by Hwang and Yoon in 1981, is a modest classification technique in formation and solicitation. The TOPSIS method is a multi-criteria decision-making method that is widely applied by decision makers in determining the strategy of a program. The hospital waste management system is a problem that requires a strategic decision-making approach. To be able to provide strategic decision results and solve the best solutions so that they can be implemented, this research uses the TOPSIS method. The TOPSIS technique selects a strategy that is concurrently closest to the positive ideal solution and furthest from the negative ideal solution. The positive ideal solution enhances value requirements while minimizing efficiency, while the negative ideal alternative maximizes cost requirements while eliminating value of the system. TOPSIS leverages characteristic metadata, gives alternate cardinal scores, and does not need characteristic desire to be consistent (Behzadian et al., 2012; Putra et al., 2021). In addition, input variables should be quantitative, uniformly growing or reducing, and have equivalent units for this strategy to be used. Figure 1 depicts Hwang and Yoon's (1981) step-by-step approach for implementing TOPSIS. Following the creation of the first decision matrix, the method starts with the normalization of the decision matrix. Step 2 involves the construction of a weighted normalized choice matrix, followed by Step 3's determination of the positive and negative ideal solutions and Step 4's calculation of the separation steps for each option. The technique finishes by determining the coefficients of relative closeness. Alternative (or candidate) sets may be ranked by closeness coefficients in decreasing order.

Step1: Build a normalized decision matrix

$$r_{ij} = x_{ij} / \sqrt{\sum X_{ij}^2} \quad for\ i = 1, \dots . m; j = 1, \dots . , n, (1)$$

Where x_{ij} and r_{ij} are the original and normalized scores of the decision matrix

Step 2: construct a weighted normalized decision matrix

$$v_{ij} = w_j\, x_{ij} \quad (2)$$

Where w_j is the weight for criterion j

Step 3: Determine the positive ideal solution and the negative ideal solution

$$A^* = \{\ v_1^*, \dots ., v_n^*\ \}\ (3)\ Positive\ ideal\ solution$$

Where $v_1^* = \{$ max (vij) if j $\in J$; min $(v_1^*)\ if\ j\ \in J'\}$ r_{ij}

$$A' = \{\ v_1', \dots ., v_n'\ \} \quad (4) \quad Positive\ ideal\ solution$$

Where $v_1' = \{$ min (vij) if j $\in J$; max $(v_1')\ if\ j\ \in J'\}$ r_{ij}

Step 4: Calculate the separation steps for each alternative

The separation obtained from the positive ideal alternative

$$S_i^* = [\ \sum(\ v_i^*, \dots ., v_{ij})^2\ ]^{1/2}\ i = 1, \dots, m\ (5)$$

The same way for the separation of negative ideal alternatives:

$$Si_j' = [\sum(\ v_i', \dots ., v_{ij})^2\ ]^{1/2}\ j = 1, \dots, m\ (6)$$

$$A' = \{\ v_1', \dots ., v_n'\ \} \quad (4) \quad Negative\ \ ideal\ Solution$$

Step 5: Calculate the relative closeness to the ideal solution C_i^*

$$C_i^* = S_i' / (S_i^* + S_j'), \quad (7) \quad 0 < C_i^* < 1$$

Choose alternative C_i^* $which\ is\ close\ to$ 1

Figure 1 TOPSIS method procedure

Based on the description of the method, to obtain information related to the criteria and alternatives, a questionnaire was made. The questionnaire consists of two stages, where in the first stage respondents are asked to provide answers related to the criteria or factors used in the decision-making strategy. Furthermore, from the results of the first stage of the questionnaire, a second questionnaire was compiled in the form of pairwise comparisons on each criterion or factor of the decision-making strategy. This questionnaire uses open-ended questions to explore more information related to the criteria and alternatives. Data was collected using a questionnaire distributed to three people from various fields: hospital waste management experts, academics, and the environmental service. Several reasons were used to determine respondents in the TOPSIS method, among others: the decision-making process for the hospital waste management strategy does not require all stakeholders so that only decision makers in hospitals are involved. Moreover, according to Munier et al., (2019) highlight the individuals who oversee projects and are accountable for the best selection. Theirs is the ultimate decision-making responsibility. In addition, the determination of the number of respondents is based on the ease of communication due to the time limit of the study. Furthermore, from the questionnaire results, the next step is to give weight to each criterion so that the stages of problem-solving can be carried out using the TOPSIS method.

3. Result and Discussion

3.1. Result

Decision criteria are the guiding concepts, objectives, norms, criteria, and conditions used by an organization or team to select an alternative or make a determination. These factors let teams choose a plan of action from a variety of possibilities. They improve the team's decisions' quality, rationality, and fairness. Alternatives are evaluated by criteria. They are determined based on the nature and qualities of the options, which can vary between projects. The stakeholders and the policy maker must set criteria in such a way that they consider what each stakeholder want and which components the scenario encompasses. From the questionnaire results submitted to the party responsible for managing medical waste in the hospital, information related to the criteria and alternatives is summarized in the table below.

Table 1. Criteria for medical waste management

ID	Criteria	Weight	Status
C1	Technical infrastructure	20	Cost
C2	Equipment safety	15	Benefit
C3	Compliance level	5	Benefit
C4	Leader support	10	Benefit
C5	Area vulnerability	7	Cost
C6	Skills and knowledge of the workforce	8	Cost
C7	Work method	10	Benefit
C8	Commitment	10	Benefit
C9	organization management System	15	Benefit

Based on the results of the questionnaire, information was obtained that there were nine criteria used in making hospital waste management decisions. In addition, the results of the questionnaire also show the weight of each criterion. Furthermore, Table 1 above also provides information that there are two statuses for each criterion, namely Benefit and Cost. Benefit is an advantage or benefit obtained from hospital waste management. Meanwhile, cost is the loss or risk that will be accepted if the hospital waste management fails.

Alternatives are possible endeavors, as well as possibilities and methods, that must be determined in order to achieve the goals. These are typically picked collaboratively by stakeholders and company departments (engineering, accounting, financial, human resources, environment), which typically provide information regarding the company's capability, experience, and financial requirements for such projects. Furthermore, the alternatives are shown in Table 2 below.

Table 2. Alternatives for medical waste management

No	Alternative
A1	SOP Improvements
A2	Environmentally friendly technology investment
A3	3R Campaign
A4	Socialization for employees and visitors

Based on these results, the respondents provide scores by comparing the alternatives on each criterion. Pairwise comparison of each alternative on each criterion using the scale developed by Saaty (1980). Furthermore, Table 3 provides information on the results of pairwise comparisons for each alternative on each criterion. For example, a score of 9 (which means the importance of one over the other is emphasized in the highest possible order) is the respondent's choice when asked to compare the alternative SOP Improvements with Environmentally friendly technology investment. The results of the scoring are shown in Table 3.

Table 3. The results of the comparison of alternatives on each criterion

ID	Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	SOP Improvements	9	9	9	8	9	9	9	9	9
A2	Environmentally friendly technology investment	9	9	7	7	8	8	7	7	8
A3	3R Campaign	8	8	8	7	7	7	7	7	7
A4	Socialization for employees and visitors	7	7	7	7	6	7	8	7	8

Then the normalization calculation is performed on each matrix using formula 1. When selecting criteria in a Multi Criteria Decision Making (MCDM) scenario, they are often chosen by the decision makers to address various elements in various sectors, related to alternatives, and in accordance with the wishes of stakeholders. Thus, the Technical infrastructure criteria with performance values can be achieved (in any number of units or otherwise). Therefore, for the MCDM process to work with this data, it is important to convert all the data to the same unit. The term for this is normalization. The overall results are shown in Table 4.

Table 4 Normalized matrix for each criterion based on alternatives

X1	X2	X3	X4	X5	X6	X7	X8	X9
16.5831	15.2643	15.5885	14.5258	15.1658	15.5885	15.5885	15.0997	16.0624

Based on these results, it becomes the basis for calculating the normalized performance rating (r_{ij}). When selecting criteria in a Multi Criteria Decision Making (MCDM) scenario, they are often chosen by the decision makers to address various elements in various sectors, related to alternatives, and in accordance with the wishes of stakeholders. Thus, the Technical infrastructure criteria with performance values can be achieved (in any number of units or otherwise). Therefore, for the MCDM process to work with this data, it is important to convert all the data to the same unit. The term for this is normalization. Completely the results of these calculations are summarized in Table 5.

Table 5. Normalization Matrix

ID	Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9
	Normalization	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**
A1	SOP Improvements	0.5427	0.5896	0.5774	0.5507	0.5934	0.5774	0.5774	0.5960	0.5603
A2	Environmentally friendly technology investment	0.5427	0.5896	0.4491	0.4819	0.5275	0.5132	0.4491	0.4636	0.4981
A3	3R Campaign	0.4824	0.5241	0.5132	0.4819	0.4616	0.4491	0.4491	0.4636	0.4358
A4	Socialization for employees and visitors	0.4221	0.4586	0.4491	0.4819	0.3956	0.4491	0.5132	0.4636	0.4981

Based on the weighting results given by the stakeholder responsible for medical waste management, as shown in Table 6, the weighted criteria were calculated in Table 6.

Table 6 Weighting criteria

Alternative	C1	C2	C3	C5	C5	C6	C7	C8	C9
Weight (W)	20	15	5	10	7	8	10	10	15

The calculation of the normalized weight rating is using formula 2. Overall, the calculation results are shown in Table 7.

Table 7. The results of the calculation of the normalized weight rating

Weighted criteria	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
A1	10.8544	8.8441	2.8868	5.5074	4.1541	4.6188	5.7735	5.9604	8.4047
A2	10.8544	8.8441	2.2453	4.8190	3.6925	4.1056	4.4905	4.6359	7.4709
A3	9.6484	7.8615	2.5660	4.8190	3.2310	3.5924	4.4905	4.6359	6.5370
A4	8.4423	6.8788	2.2453	4.8190	2.7694	3.5924	5.1320	4.6359	7.4709

Based on Table 7 provides information related to the weighted normalization calculation for each alternative on each criterion. Furthermore, calculations are carried out to determine the positive and negative ideal solutions base on formula 3. Based on the questionnaire results obtained, the results of alternative attributes on each criterion as shown in Table 8.

Table 8. Alternative attributes for each criterion

Alternative	C1	C2	C3	C4	C5	C6	C7	C8	C9
Attribute	Cost	Benefit	Benefit	Benefit	Cost	Cost	Benefit	Benefit	Benefit

Based on the results of the questionnaires that have been distributed to respondents, information is obtained that each criterion has a different status, such as benefits that describe the benefits of the criteria and costs that illustrate costs or losses. Calculation of the weighted distance value of each alternative to the positive and negative ideal solutions using formulation 4. The results are shown in Table 9.

Table 9. Maximum and minimum values of each criterion

Positive	A+	Negative	A-
Y1+	10.8544	Y1-	9.6484
Y2+	8.8441	Y2-	7.8615
Y3+	2.8868	Y3-	2.2453
Y4+	4.8190	Y4-	5.5074
Y5+	4.1541	Y5-	3.2310
Y6+	4.6188	Y6-	4.1056
Y7+	5.7735	Y7-	4.4905
Y8+	4.6359	Y8-	4.6359
Y9+	8.4047	Y9-	7.4709

Table 10. Maximum and minimum values for each criterion

A+	10.854	8.844	2.887	4.819	4.154	4.619	5.774	4.636	8.405
A-	9.648	7.861	2.245	5.507	3.231	4.106	4.491	4.636	7.471

The next stage is to determine the preference value of each criterion using formula 5.

Table 11. Preference results for each alternative

Alternative Distance	Positifve (+)	Negative (-)	(D+) + (D-)	V	Ranking
A1	1.4928	2.8670	4.3598	0.6576	1
A2	1.8456	1.7627	3.6083	0.4885	2
A3	3.0924	1.3085	4.4010	0.2973	4
A4	3.7877	1.9448	5.7325	0.3393	3

Table 11 provides information related to the results of calculating alternative preferences at positive and negative distances. Furthermore, from the calculation results, the highest preference value for alternative A4 (Socialization for employees and visitors) is around 5.7325 and the smallest value for alternative A2 (technology investment) is around 3.6083. Furthermore, the results of the calculation of the preference value then become the basis for determining the distance to each alternative. Thus, from the calculation results obtained the largest distance is Alternative A1 (SOP Improvements) with a weight of 0.6576. This places SOP Improvements as the first alternative in making hospital waste management decisions

3.2. Discussion

From the results of the analysis using the TOPSIS method, it can be seen that the first alternative based on expert preference is SOP improvement with a weight of about 0.6576. Thus, hospital management can consider proposed improvement strategies, namely making SOPs and hospital waste reduction and recycling regulations. The first internal intervention that can be done is to make regulations regarding avoiding waste generation. Reducing medical waste can be made to avoid using B3 materials if there are other alternatives, managing materials that can produce health problems and environmental pollution, and managing the procurement of chemicals and pharmaceuticals to avoid accumulation and expiration. Then the amount of medical waste can be reduced by a strict separation between non-medical waste and medical waste.

The following program is to intervene in hospital visitors. In general, hospital visitors are difficult to control or limit, and in fact, most of the waste is generated by hospital visitors. However, Hospital can regulate hospital regulations to provide a waste bin that separates waste based on its characteristics (at least separating medical waste, organic non-medical waste, and inorganic non-medical waste). If the waste is still allowed to be recycled, it can be exchanged at the Waste Bank. Install signs related to waste management and posters calling for proper waste management, for example, appeals such as "throw out trash in its place."

In a previous study, namely a study conducted by Fadhullah et al. (2022), if there is an increase in waste separation according to its characteristics, it will significantly reduce the volume of waste generated and processed. Then it will have an impact on reducing costs incurred by hospitals to process waste. Both interventions (internal and external) can reduce the costs incurred by the Hospital to manage the waste. The intervention can reduce the frequency of transporting non-medical solid waste to normal and reduces the volume of medical waste that the private sector will process. Based on the priority selection of the main factors in the proposed strategy for improving the solid waste management process and the environmentally friendly technology investment, it is possible to carry out both interventions.

Based on the description above, hospitals can make SOPs and specific hospital regulations, distinguishing regulations to regulate waste management from the hospital management (office staff, medical staff, and cleaning services) and visitors. Supported by one of the studies conducted by Sapkota et al., the Nepalese government hospital has succeeded in improving the process of managing the waste generated by intervening in SOPs and hospital regulations regarding waste management. The improvement of process waste management starts by consistently complying with applicable national and international laws and regulations. Develop a recycling plan and minimize waste. Hospital staff is given training or information related to solid waste management processes. As a result, the pre-intervention showed that the state of hospital waste management was bad (score 26%) and had improved post-intervention to be very good (score 86%)(Sapkota et al., 2014).

4. Conclusions

This paper presents the application of the TOPSIS method to solve the problem of selecting the best alternative for hospital waste management. Based on the results of research and discussion, conclusions can be drawn about waste management strategies in hospitals. Several previous studies have analyzed this problem using different methods. Moreover, various criteria are used in determining the decision-making strategy, such as technical infrastructure, equipment security, compliance level, leadership support, regional vulnerability, workforce skills and knowledge, work methods, commitment, and management system (Organization). In addition, there are several alternatives that the hospital has chosen in waste management, such as improving SOPs, investing in environmentally friendly technology, 3R campaigns, and outreach to employees and visitors. Furthermore, the results of the selection of alternative strategies using the TOPSIS method obtained the order of priority strategies as follows: Improvement of SOP with a weight of 0.6576. Furthermore, alternative investments in green technology, 3R campaigns, and outreach to employees and visitors weigh approximately 0.4885, 0.2973, and 0.3393, respectively.

In this study, we have not discussed the consensus and dynamics of determining criteria and other alternatives, especially in the decision-making group. Any topics related to group interaction will be topics of interest for group decision making, and will be kept for future research. This research can be a reference for similar research in waste management in hospitals.

References

Abd El-Salam, M.M. 2010. Hospital waste management in El-Beheira Governorate, The Egyptian Journal of Environmental Change 91, 618–629.

Abessi, O., and Saeedi, M. 2014. "Hazardous Waste Landfill Siting using GIS Technique and Analytical Hierarchy Process. EnvironmentAsia 7(2),104–111.

Ali, M., Yadav, A., Anis, M., and Sharma, P. 2015. "Multiple Criteria Decision Analysis Using Dea-TOPSIS Method for Hazardous Waste Management: A Case Study of The USA," International Journal of Information Technology and Management 7(3),1–17.

Alves, M.C.M., Lima, B.S.L.P., Evsukoff, A.G., Vieira, I.N. 2009. Developing a fuzzy decision support system to determine the location of a landfill site. Waste Management & Research 27 , 641–651.

Anisur, R.K., Shafiul, A., Manzurul, H.M., Tarit, B. 2008. Pattern of medical waste management: Existing scenario in Dhaka City, Bangladesh. BMC Public Health 8, 36.

Ariasih, N.K., Bayupati, I.P.A., Putra, I.K.G.D. 2015. Sistem pendukung keputusan pemilihan lokasi TPA sampah menggunakan metode min_max inference fuzzy. Jurnal Teknologi Elektro 14 (1), 7–10.

Behzadian, M,. Otaghsara, S.K., Yazdani, M., Ignatius, J. 2012. A state-of the-art survey of TOPSIS applications: Review, Expert Systems with Applications 39, 13051–13069.

Boskovic, G. Jovicic, N. 2015. Fast methodology to design the optimal collection point locations and number of waste bins: A case study. Waste Management & Research 33 (12), 1094 – 1102.

Buyukozkan, G., and F. Gocer. 2016. Selection of medical waste logistic firms by using AHP-TOPSIS methodology, International Journal of Biology and Biomedicine 1.

Chartier, Y. 2014. Safe Management of Wastes from Health-Care Activities; World Health Organization: Geneva, Switzerland.

Chartier, Y., Pieper, U., Prüss, A.E.A. 2014. Safe Management of Wastes from Health Care Activities; World Health Organization: Geneva, Switzerland.

Chabuk, A., Al-Ansari, N., Hussain, H.M., Knutsson, S., Pusch, R. 2016. Landfill site selection using geographic information system and analytical hierarchy process: A case study Al-Hillah Qadhaa, Babylon, Iraq. Waste Management & Research 34 (1), 1–11.

Ho C., Chen, M. 2017. Appling the Analytic Hierarchy Process as the Risk Evaluation Model to Improve Hospital Biomedical Waste Disposal Outsourcing Quality, International Journal of Management, Economics and Social Sciences Special Issue-International Conference on Medical and Health Informatics (ICMHI 2017) 6(S1), 230 – 243.

Coelho, L.M.G., Lange, L.C., Coelho, H.M.G. 2017. Multi-criteria decision making to support waste management: A critical review of current practices and methods. Waste Management & Research 35 (1), 3 – 28.

Diaz, L.F., Savage, G.M., Eggerth, L.L. 2005. Alternatives for the treatment and disposal of healthcare wastes in developing countries. Waste Management 25, 626–637.

Fadhullah, W., Imran, N.I.N., Ismail, S.N.S. Jaafar, M.H., and Abdullah, H. 2022. Household solid waste management practices and perceptions among residents in the East Coast of Malaysia, BMC Public Health. 22:1.

Hossain, M.S., Santhanam, A., Norulaini, N.N., Omar, A.M. 2011. Clinical solid waste management practices and its impact on human health and environment—A review. Waste Management 31, 754–766.

Ho, C.C. 2011. Optimal evaluation of infectious medical waste disposal companies using the fuzzy analytic hierarchy process., Waste Manag 31(7), 1553–9.

Hsu, P.F., Wu C.R., and Li, Y.T. 2008. Selection of infectious medical waste disposal firms by using the analytic hierarchy process and sensitivity analysis. Waste Manag 28(8), 1386–94.

Iqbal, S.T.Z., Razzaq, S. 2017. Novel Healthcare Solution for Smart Hospitals: A Qualitative Review. Biomed. Lett 3, 99–106.

Khan, B.A., Cheng, L. Khan, A.A., Ahmed, H. 2019. Unsafe small clinics practices causing new HIV outbreaks in Pakistan. J. Hosp. Infect.

Kharat, M.G., Kamble, S.S., Kamble, S.J., Dhume, S..M., Raut, R.D. 2016. Modeling landfill site selection using an integrated fuzzy MCDM approach. Modelling Earth System Environment 2 , 53.

Liao, C., and Ho, C.C. 2014. Risk management for outsourcing biomedical waste disposal– Using the failure mode and effects analysis. Waste management 34(7), 1324-1329.

Manga, V.E., Forton, O.T., Mofor, L.A., Woodard, R. 2011. Health care waste management in Cameroon: A case study from the Southwestern Region. Resource Conservation & Recycling 57, 108–116.

Munier, N., Hontoria, E., Jiménez-Sáez, F. 2019. Strategic Approach in Multi-Criteria Decision Making : A Practical Guide for Complex Scenarios, Springer. ProQuest Ebook Central, http://ebookcentral.proquest.com/lib/polije-ebooks/detail.action?docID=5654954 (Accessed: May 25, 2022)

Opricovic, S., Tzeng, G.H. 2004. Compromise solution by MCDM methods: a comparative analysis of VIKOR and TOPSIS. European Journal of Operation Research 156 (2), 445–455.

Patil, A.D., Shekdar, A.V. 2001. Healthcare waste management in India. Journal of Environment Management 63, 211–220.

Patwary, M.A., O'Hare, W.T., Sarker, M.H. 2011. Assessment of occupational and environmental safety associated with medical waste disposal in developing countries: A qualitative approach. Saf. Sci. 49, 1200–1207.

Paul, S. 2012. Location allocation for urban waste disposal site using multi-criteria analysis: A study on Nabadwip Municipality, West Bengal, India. International Journal of Geomatics and Geosciences 3 (1), 74 – 88.

Prüss, A., Giroult, E., Rushbrook, P. 1999. Safe Management of Wastes from Health-Care Activities; World Health Organization: Geneva, Switzerland.

Putra, G.M., Siddik, M., Lubis, A.P., Nuriadi, A. 2021. Application of TOPSIS Method in Exemplary Selection at the Tanjungbalai District Court, Virtual Conference on Engineering, Science and Technology (ViCEST) 2020, Journal of Physics: Conference Series, 1933, 012063.

Rimantho, D., and Tamba, M. 2021. Usulan Strategi Pengelolaan Sampah Padat di TPA Burangkeng Bekasi dengan Pendekatan SWOT dan AHP, Jurnal Ilmu Lingkungan 19 (2), 383-391.

Saaty, T.L. 1980. The Analytic Hierarchy Process. McGraw-Hill, New York, USA.

Sapkota, B., Gupta, G.K., and Mainali, D. 2014. Impact of Intervention on Healthcare Waste Management Practices in a Tertiary Care Governmental Hospital of Nepal, BMC Public Health 14(1), 1–8.

Shaw, K., Shankar, R., Yadav, S.S., Thakur, L.S. 2012. Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. Expert Systems with Applications 39 (9), 8182–8192.

Singh, A.P., Dubey, S.K. 2012. Optimal Selection of a Landfill Disposal Site Using a Modified Fuzzy Utility Approach. Fuzzy Information and Engineering 3 , 313-338. DOI 10.1007/s12543-012-0118-9.

Torabi-Kaveh, M., Babazadeh, R., Mohammadi, S.D., Zaresefat, M. 2016. Landfill site selection using combination of GIS and fuzzy AHP, a case study: Iranshahr, Iran. Waste Management & Research 34 (5), 438-448.

Windfeld, E.S., Brooks, S.L. 2015. Medical waste management—A review. Journal of Environment Management 163, 98–108.